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Think Cities: the accelerator for sustainable planning

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Abstract—The Think-Cities® project aims to develop a digital tool for smart city to evaluate urban projects. Think-Cities® transforms the planning sector by offering a smart application that values the territories and connects its actors. A proof of concept (URBAN THINK®) has been developed in SaaS mode in partnership with Rennes Métropole. Think-Cities® aims to bring major evolutions to the URBAN THINK® functionalities and will thus offer a global tool for observing territories and evaluating development projects. Always focused on a Web mapping platform, based on benchmark indicators, to evaluate and simulate the impacts of development projects and to recommend optimal hypotheses about these impacts, Think-Cities® also opens up to dynamic data (IOT) and therefore to new types of indicators complementing its catalog of decision support criteria. Grafted onto a collaborative 3D mapping platform in SAAS mode, Think-Cities® transforms the spatial planning sector by offering national (HQE, ADEME, ...), international (LEED, ...) and user-specific reference indicators. to evaluate and simulate the impacts of development projects.

Index Terms—Smart cities, Semantic Caching, Time series

I. INTRODUCTION

A. Context

The territories are facing increasing pressure on the sustainability of the development projects they undertake. Launching new projects involves a 360 ° vision of their environmental, socio-economic or technological impacts. The data produced by the local authorities and the private actors evolve very quickly and reflect the inventory of the territories. They are invaluable to qualify the insertion of new projects, access to transport, services, social mix, green spaces etc.

B. Problem

In such a context, the problem is: how to exploit the growing amount of data available? There is a lot of data but they remain difficult to exploit (raw data, heterogeneous formats), scattered or difficult to access.

C. Existing work

There are more and more offers about smart city applications. specifically of visualization solutions (LandSim3D -

Existing tools	Indicators	targeted data	simulate tool	free evaluated area
Decideom	0	✓ 1	✗ 0	✗ 0
Kermap	3	✓ 1	✗ 0	✗ 0
LandSim3D	0	✓ 1	✓ 1	✗ 0
Nest	6	✓ 1	✓ 1	✗ 0
MCMA	0	✓ 1	✗ 0	✗ 0
Think-Cities	< 50	✓ 1	✓ 1	✓ 1

Fig. 1. Other tools Comparaison

Bionatics¹), raw data reading (MCMA -Magellium / Urbanis) or evaluation on specific topics (NEST²). As illustrated by Figure 1, Think-Cities® is distinguished by its global approach from the point of view of the subjects evaluated, its interactivity with the notions of simulation and optimization of projects, but especially by the enrichment of the data and the analysis provided by SETUR urban planning experiences and knowledge.

Within smart cities, managing data series is crucial. Data series have attracted a lot of attention. The management of large amount of data in general has attracted particular attention in recent years. Many works, especially by industrialists such as Google, Microsoft, Facebook, IBM or Yahoo! have been conducted with a variety of file management systems (GFS [1], HDFS³, etc.) of runtime environments (MapReduce [2], Tez [3], Spark [4]) or data query systems (Hive [5], Jaql [6], Pig [7], SCOPE [8]).

Managing time series raises performances issues. Perfor-

¹<https://mybionatics.com/landsim-3d/>

²<https://www.nobatek.inef4.com/produits/nest/>

³<https://hadoop.apache.org/>

mance optimization in databases has been studied for years, using indexing, materialized views, prefetching or caching. In particular, semantic caching [9], [10] enables to rewrite queries so as to reuse local results from previous requests. Nevertheless, a cache is efficient only if it is tuned for a given context. The combination of various indicators and time series lead to a major challenge: how to select relevant caching strategies?

D. Contributions

Think-Cities® aims to provide significant time savings to users in their daily tasks through the holistic assessment of their territory and development projects, the valuation of data produced and the cross-referencing of data sources allowing an immediate response to given questions.

- Evaluate/compare geographic areas according to referenced indicators,
- Simulate the impact of new developments,
- Recommend the adjustments proposed by the experts (users) with the best impacts on their sector, based on optimal indicators for these developments,
- Demonstrate in a concrete way the use that can be made of data to enhance the attractiveness of a territory.
- Integrate dynamic data on some existing indicators and new indicators.

E. Paper Organization

This paper is organized as follows. Section 2 defines the context and the motivation. Section 3 presents the Think Cities solution. Section 4 focuses on data management, introducing Warp 10. Section 5 discusses optimization with semantic caching. We review related works in Section 6 and conclude in Section 7.

II. PRELIMINARIES

A. Smart cities

“The smart city is a new concept of urban development. It aims to improve the quality of life of city dwellers by making the city more adaptive and efficient, using new technologies that rely on an ecosystem of objects and services. The scope covering this new mode of management of cities includes: public infrastructures (buildings, street furniture, home automation, etc.), networks (water, electricity, gas, telecoms); transport (public transport, roads and smart cars, carpooling, so-called soft mobility - by bike, on foot, etc.); e-services and e-administrations.” (CNIL⁴) Think Cities is a e-service response to the lack of use cases of data exploitation. Think Cities is a tool to help with the decision for sustainable development in order to improve the quality of life of city dwellers.

⁴<https://www.cnil.fr/>

B. Geo Time SeriesTM

A time series is a series of data points indexed (or listed or graphed) in time order. Most commonly, a time series is a sequence taken at successive equally spaced points in time. Thus it is a sequence of discrete-time data. Examples of time series are heights of ocean tides, counts of sunspots, and the daily closing value of the Dow Jones Industrial Average.

Geo Time SeriesTM are time series which contain also the location involvement.

In a Smart Cities context, data coming from mobility meters or building sensors can be expressed into Geo Time SeriesTM: an evolution of the traffic status over a time period at a specific location or a bus driving across a city with its location and occupation as a measurement.

C. Form-based Semantic caching

Semantic caching [9] [10] allows to exploit resources in the cache and knowledge contained in the queries themselves. As a consequence, it enables effective reasoning, delegating part of the computation process to the cache, reducing both data transfer and the load on servers.

When a query is submitted to a cache, it is split into two disjoint pieces: (1) a probe query, Q_{probe} , which retrieves the portion of the result available in the local cache, and (2) a remainder query, Q_{remain} , which retrieves any missing tuples in the answer from the server. If the remainder query exists, then it is sent to the server for processing.

Example 1: Consider a semantic cache storing an entry e $date < '19/11/2019 - 0 : 00 : 00'$ and a posed query q $city = 'Rennes'$. In that case a probe query $probe$ is $date < '19/11/2019 - 0 : 00 : 00' \wedge city = 'Rennes'$ can be processed in the cache while a remainder query $remainder$ $date \neq '19/11/2019 - 0 : 00 : 00' \wedge city = 'Rennes'$ has to be sent to the server.

Fig. 2. Example of form-based query.

Form-based caching makes it possible to optimize queries submitted via HTML forms [11], [12], as illustrated in Figure 2. This form enables us to optimize processing through query templates, which are parameterized with values used to fill in the forms. In particular, form-based caching may rely on semantic caching, by evaluating a query over the entries of the cache.

D. Motivation

Think Cities aims to provide an overview of territories using various data sources. In particular it provides enriched data, via

more than 50 indicators. Among data to be considered, time series are more and more present and available. This leads to address efficient time series management on urban planning, land and smart urban models problematics. In particular, Think Cities optimizes query processing using cache, more precisely form-based semantic caching on time series.

III. THINK CITIES

Think Cities aims to provide an overview of territory according to (inter)national standards (HQE, LEED) and evaluation criterias. On one hand, Urban-Think is able to define an urban project with 6 core values: (1) water management; (2) energy and climate; (3) societal Approaches; (4) mobility - accessibility; (5) Ecosystem Biodiversity and (6) Waste management. On the other hand, Think cities can provide increased values such as proximity of services, health, risks, carbon footprint etc. In total, Think Cities makes them available more than 60 indicators. Figures 3 and 4 illustrate two of these indicators, respectively traffic and waste. More indicators are presented in Appendix.

Think Cities, as illustrated by Figure 5, considers two main classes of data sources: pseudo static and dynamic data. On one hand, Think Cities relies on traditional DBMS and their corresponding GIS extension, in particular on PostgreSQL and PostGIS, to manage pseudo static data. On the other hand, Warp10 is used to manage dynamic data, as detailed in Section IV. Data processing is optimized through caching, as discussed in Section V.

IV. WARP 10TM

The Warp 10TM ⁵ core platform is built to manage and simplify time series processing. It includes a Geo Time SeriesTM database and a companion analytics engine. Each one can be used separately but they work great together.

A. Geo-Time Series

Each measurement has a specific time, a value and optional spatial metadata such as geographic coordinates and/or elevation. Those augmented measurements are what we call Geo Time SeriesTM (GTS).

Figure 6 illustrates a GTS. The header introduces the class (engine speed) and some labels (serial number and vehicle engines). The data points consist of a timestamp, a latitude, a longitude, an elevation and a value. The bottom part provide additional key/value pairs (vehicle owner and last maintenance).

B. WarpScriptTM

Warp 10TM dedicated analytics language, called WarpScriptTM, is specifically designed for complex analysis of Time Series data at any scale. An example of Warp 10 is illustrated by Figure IV-B. WarpScriptTM provides more than 1000 functions ranging from simple statistics to complex algorithms such as pattern and anomaly detection.

```
[
  $read_token
  'gov.noaa.storm.wind'
  {}
  '2015-02-01T00:00:00.000z'
  '2015-01-01T00:00:00.000z'
] FETCH 'fetch_wind' STORE
[ $fetch_wind bucketizer.mean NOW 1 d 0 ]
BUCKETIZE 'bucketizedWind' STORE
```

WarpScriptTM is a data flow programming language. This differs from a query language which can fetch data and perform simple computations. WarpScriptTM has the power of a Turing Complete programming language, with conditionals, loops, and asynchronous transfer of control.

The WarpScriptTM Execution Engine is the part of the Warp 10TM Platform which runs the WarpScriptTM code, simply submit code via a HTTP request, the engine will execute it close to where the data reside and will return the result as a JSON object which can be integrated into an application.

The WarpScriptTM language is also integrated in many existing data processing languages and environments such as R, Python, Zeppelin, Jupyter, Spark, Pig, Storm or NiFi, with the ability to use the same WarpScriptTM code across all those environments. This greatly increases efficiency.

In WarpScriptTM, as in all concatenative programming languages, every expression is a function and juxtaposition of expressions denotes function composition, in the spirit of how Unix pipelines work.

WarpScriptTM manages a data pipeline with which all functions interact, getting their arguments by emptying the pipeline, and filling it with their results. The data pipeline is passed from function to function during the execution of WarpScriptTM code.

The Warp 10TM Analytics Engine, the WarpScriptTM Execution Engine of Warp 10TM accessed via the /api/v0/exec endpoint, returns a JSON list which contains the elements of the data pipeline after the code execution. The first element of this list contains the most recent element of the pipeline.

V. FORM-BASED SEMANTIC CACHING

Figure 7 presents an overview of our form-based semantic caching approach. It relies on 3 phases: (1) form-based querying, (2) semantic processing, and (3) time-series optimization.

Form-based query processing enables users to access data via template queries. For example, a user often makes a form query, such as "Showing devices: id_1, id_2, \dots, id_n with the conditions: c_1, c_2, \dots, c_m ".

The obtained parameterized queries can then be decomposed into a probe queries, and a remainder query, as shown in Example 2.

Example 2: Assuming that a semantic caching stores the result of a query to take the sum of rain water in January, 2019 among cities in France. The other result of summing of

⁵<https://www.warp10.io>

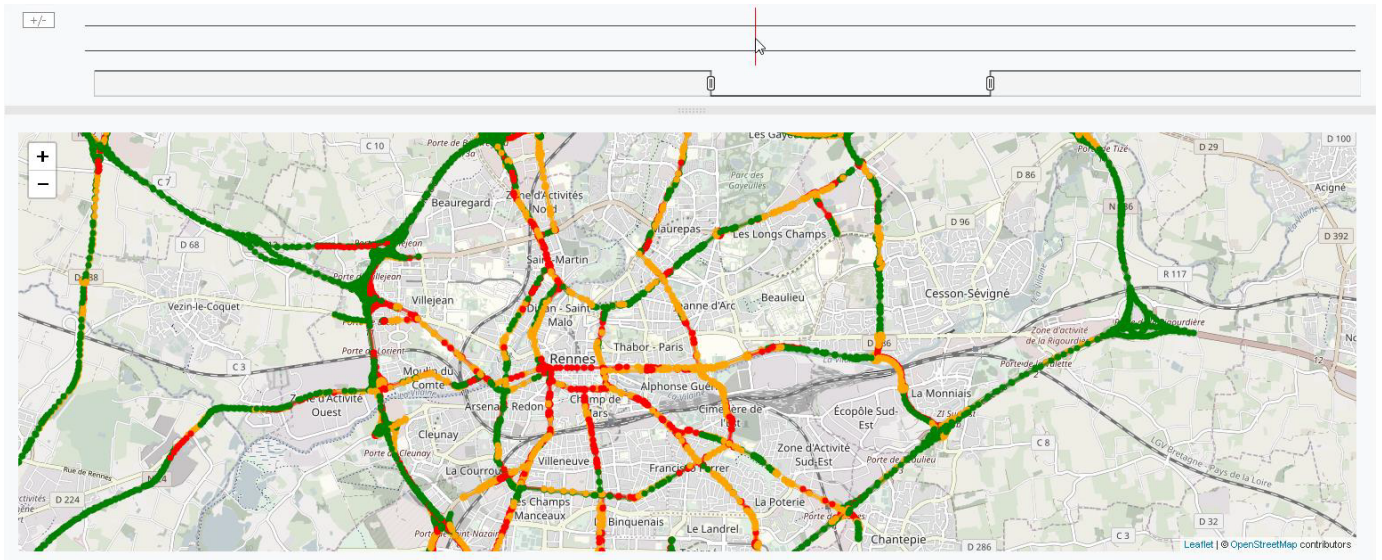


Fig. 3. Example of traffic indicator



Fig. 4. Example of a waste indicator

rain water in Rennes, in twelve months, 2019 is stored in the semantic caching also. The next query compares the sum rain water in Rennes between January, 2019 and 2018. Hence, the probe query can be taken from the cache is summing of rain water in Rennes in January, 2019. The remainder query should be sent to the server to have summing rain water in Rennes in January, 2018.

The remainder queries will then be translated into instruction in Warp10, making it especially for pushing down filters (selection or projection for instance).

Data in the cache are represented as JSON data⁶, as illustrated in Figure 8.

Obviously, cache management raised several questions for example regarding duplication [9], [10] or consistency [13]. Detailing these aspects is out of the scope of this paper which aims to provide an overview of the Think Cities project.

⁶https://www.warp10.io/content/03_Documentation/03_Interactive_with_Warp10/04_F

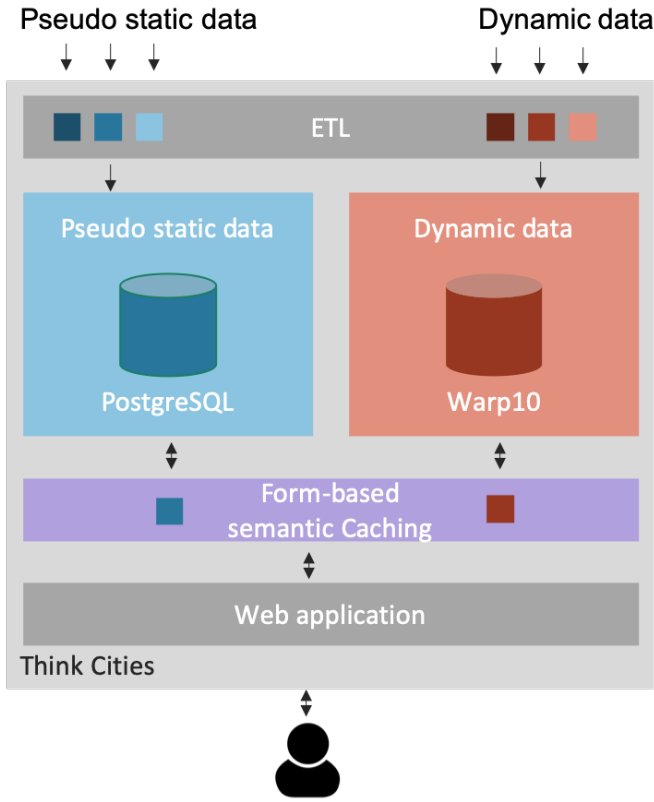


Fig. 5. Overview of Think Cities

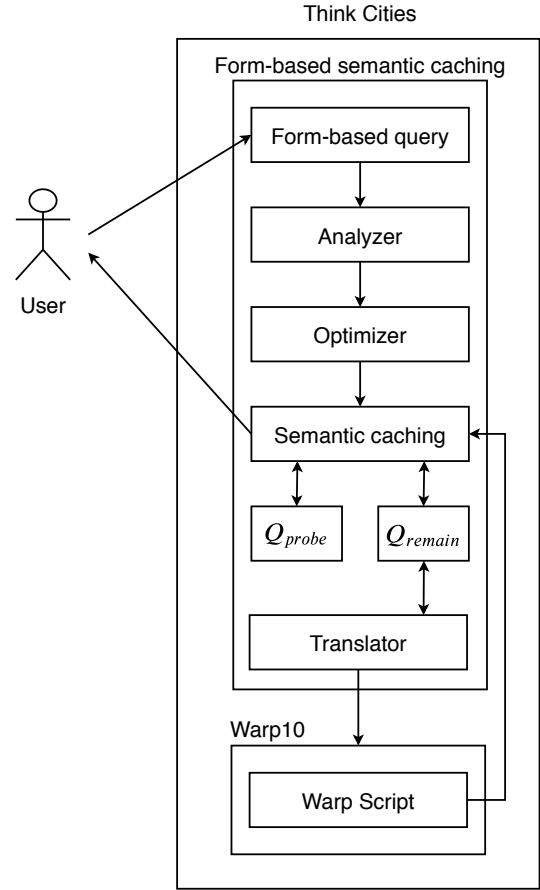


Fig. 7. Form-based semantic caching and Warp10.

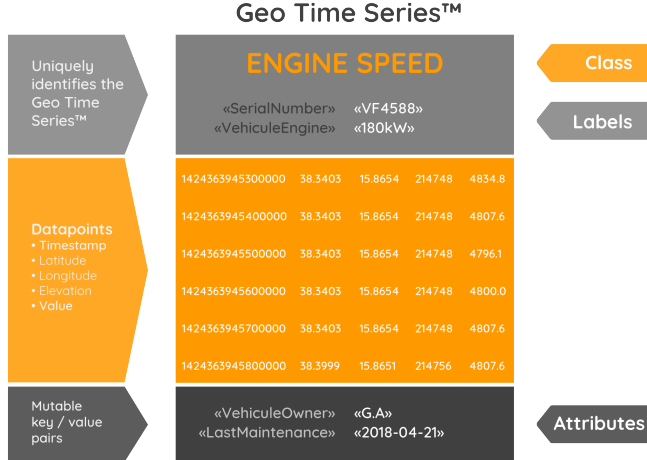


Fig. 6. Warp 10™ Geo-Time Series representation

VI. RELATED WORK

This section presents some of the main works related to smart cities (see Subsection VI-A), time series (see Subsection VI-B) and semantic caching (see Subsection VI-C).

A. Smart city

This area is the intersection of two worlds, digital and urban planning towards a tool for decision support. The existing

```
[{"c": "class",
  "l": {"label0": "value0", "label1": "value1"},
  "a": {"attr0": "value0"},
  "i": "1",
  "v": [[1380475081000000, 3.14],
        [1380475081500000, 48.0, -4.5, 2.5],
        [1380475082000000, 10000000, 3.0]],
  {"i": "1",
    "v": [[1380475083000000, 48.1, -4.5, 11000000, 42.0]]}]
```

Fig. 8. Example of JSON data.

tools often come from one of these two worlds. The first approach often offers to enrich technologies without an urban planning approach. Also, these tools are often difficult to handle. Experiences show that there is a gap between digital players and territory actors in understanding issues. MCMA (Magellium / Urbanis) presents only raw descriptive elements related to the application of the law of grounds, while Think-Cities® offers professional interpretations of data.

Think Cities® is a smart interactive platform for an online assessment of urban planning and architectural projects. Think Cities® compiles heterogeneous data (spatial, forms, IoT, etc.), the General Data, and visualize it to make the best decisions, at every step of a given project, at any scale. This tool leverages more than 50 key indicators to process data and produces

6 global themes to facilitate analysis: Water Management, Energy Climate, Biodiversity, Social climate, Waste Management, Mobility Accessibility. Think-Cities® is distinguished by its global approach. For example, NEST (nobatek) offers only 6 building-related indicators, while Think-Cities® covers several themes with more than 50 indicators. Think-Cities® is distinguished by its interactivity by offering a user-made free cut allowing for greater freedom and finer analysis. Existing tools allow the analysis of predefined sectors. Think Cities® thus helps to save time on strategic decision-making while ensuring compliance with the latest regulations and key sustainability labels. More than analyzing projects in a static mode, this tool permits to simulate projects by editing data like building, services, or road projects and to analyze them. The notion of planning over time can help to respond to the challenges of urban planning.

B. Time series

Methods for time series analysis [14], [15] may be divided into two classes: frequency-domain methods and time-domain methods. The former include spectral analysis and wavelet analysis; the latter include auto-correlation and cross-correlation analysis. In the time domain, correlation and analysis can be made in a filter-like manner using scaled correlation, thereby mitigating the need to operate in the frequency domain.

Methods of time series analysis may also be divided into linear and non-linear, and univariate and multivariate.

Those methods can be applied in a Smart Cities context. Analysis could be exploratory, prediction, forecasting, classification, outliers detection, pattern detection, and so on.

Figure 9 positions Warp10 with respect to other time series management systems, like InfluxDB⁷ or Prometheus⁸. Warp10 can thus be seen as an open source, generic and with a variety of functions solution.

C. Semantic Caching

Semantic caching has been studied in several contexts: distributed databases [9], [10], web [16]–[18] and grid computing [19]. These solutions differ in several ways. The cache can thus store query results [10] called *semantic regions* or *semantic segments*, objects to be strongly [9] or independently [19] associated to and possibly shared by predicates. Some of them focus on a specific data structure like XML [16], [18]. Efficient research, via *signature files* has been proposed for keyword based and conjunctive queries.

In previous work, we deployed P2P semantic caches, called CoopSC [20] to highlight potential money savings in the cloud, in addition to traditional time and bandwidth consumption reductions.

All these techniques are complementary to our project and can be (partially) reused to provide finely tuned caches for smart cities.

⁷<https://www.influxdata.com/>

⁸<https://prometheus.io/>

VII. CONCLUSION

This paper introduced the Think Cities project to evaluate urban projects. It discussed data management more precisely time series management and optimization via form-based semantic caching.

We are currently implementing and validating these contributions, and integrating both synthetic and real data. Future work includes heterogeneous caches management. In addition we will study traditional and specific policies for traditional and semantic caching.

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